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MEMORANDUM

TO: Beth Ledoux, King County, Water and Land Resources Division

FROM: James Packman, Taylor Associates, Inc.

DATE: 30 December 2010

SUBJECT: Cottage Lake data analysis

INTRODUCTION

This memorandum summarizes results of a data analysis effort by Taylor Associates, Inc. of data from Cottage Lake in King County, Washington and two of its associated tributaries, Cottage Lake Creek and Daniels Creek. This data analysis is intended to support King County in addressing the Total Maximum Daily Load (TMDL, Ecology 2004 and 2007) for total phosphorus in Cottage Lake as set forth by the Washington State Department of Ecology (Ecology) and the Environmental Protection Agency (EPA).

ANALYSIS APPROACH

This analysis compared concentrations of total phosphorus (TP), Orthophosphate phosphorus (Ortho-P), and Fecal Coliform bacteria (Fecals) from 2006 and 2010 to determine if a statistically significant change is observed in these parameters. We developed a work plan and analysis approach with King County (B. Ledoux, personal communication). Because of the limited scope for this analysis, we focused our approach only on basic summary statistics, box-and-whisker plots to visually show the data distribution, and *t*-tests to compare concentrations between 2006 and 2010. These years were chosen to represent before and after periods of corrective actions by King County and other groups to address phosphorus loadings to Cottage Lake.

The data used in the analysis were from monitoring stations selected to represent Cottage Lake and its two main tributaries, Daniels Creek and Cottage Lake Creek. Four stations for each analysis were selected per the scope of work. For the TP and Ortho-P analysis, data were available from the lake and both tributaries. For the Fecals analysis, data were available only from the tributaries.

Data from vertical profile station A707 in the middle of Cottage Lake were used for the TP and Ortho-P analysis. Data from the 1-meter and 2-meter depths of A707 were combined to represent phosphorus conditions in the epilimnion of the lake, which is the emphasis of the TMDL. The tributary that flows from the northwest is Daniels Creek and data used were from the DANL0,

DANL1, DANL3, and DANL9 (Fecals only) to represent the mouth of the creek and two upstream locations in the Daniels Creek watershed. Data from DANL0 and DANL1 stations were combined since they are proximally close to each other and periods of storm flows sometimes prevented access to DANL0 at the mouth of Daniels Creek near the lakeshore. The tributary from the northeast is Cottage Lake Creek and data from the COT1 station were selected to represent contributions from Cottage Lake Creek. For a map and full explanation of the monitoring approach, please refer to the project Sampling and Analysis Plan (SAP, King County 2005). Table 1 below summarizes the data used for this analysis, including the stations and number of samples collected.

Table 1. Stations and sample sizes[1].

Total Phosphorus			**Orthophosphate Phosphorus**			**Fecal Coliform Bacteria**		
Station	**2006**	**2010**	**Station**	**2006**	**2010**	**Station**	**2006**	**2010**
DANL1	14	11	DANL1	14	11	DANL1	14	12
DANL3	14	12	DANL3	14	12	DANL3	14	12
COT1	14	12	COT1	14	12	DANL9	14	14
A707[2]	27	24	A707[2]	27	23	COT1	14	13

1. For more information the specifics of how and where data were collected, see the project sampling and analysis plan (King County 2005).
2. The data set for A707 was the combination of the 1-meter and 2-meter depths at the lake profiling station A707.

The data analysis elements consisted mainly of plotting data into box-and-whisker plots to visually assess data distribution and running *t*-tests to compare data between 2006 and 2010. Box-and-whisker plots are presented in Appendix A and full statistics tests are presented in Appendix B. Conventional box-plots were used for this analysis with the minimum and maximum values indicated by the "whiskers", first and third quartiles indicated by the lower and upper bounds of the "box", and the median indicated at the inward notch in the box.

Prior to running the *t*-tests, the conventional assumptions about the data were reviewed:

1. Random and independent samples. This assumption is not applicable to this data set because samples were collected in a directed manner during storms and base flow at locations and intervals comparable to historical sampling (King County 2005).
2. Data come from a normally distributed population. For purposes of this limited analysis, it was assumed that data collected for TP, Ortho-P, and Fecals come from a normally distributed population.
3. Equal variances of the two populations being tested. Sample variances were checked for each data set and were found to range widely.

The *t*-test is most robust as a paired test where sample sizes and variances are the same between the data sets being compared. Paired *t*-tests were planned to be used per the project SAP (King County 2005); however, varying sample sizes and variances were present in the sample data – an issue known as the Behrens-Fisher problem (Zar 1996) when using *t*-tests. The Welch's *t*-test was developed for the Behrens-Fisher problem and is known to be robust for sample data with departures in variances since it uses a pooled variance from both data sets being compared in the calculation of the *t*-value. Because of the inconsistent sample sizes and range of variances in the project sample data, the Welch's *t*-test was chosen for this analysis.

The statistical hypotheses tested by the *t*-test for TP and Ortho-P are as follows:

Null hypothesis (H_o): There is no difference in arithmetic mean concentrations of TP and Ortho-P in Daniels Creek, Cottage Lake Creek, and in Cottage Lake itself between 2006 and 2010.

Alternative hypothesis (H_a): There is a difference in arithmetic mean concentrations of TP and Ortho-P in Daniels Creek, Cottage Lake Creek, and in Cottage Lake itself between 2006 and 2010.

The statistical hypotheses tested by the *t*-test for Fecals are as follows:

Null hypothesis (H_o): There is no difference in geometric mean concentrations of Fecal Coliform bacteria in Daniels Creek and Cottage Lake Creek between 2006 and 2010.

Alternative hypothesis (H_a): There is a difference in geometric mean concentrations of Fecal Coliform bacteria in Daniels Creek and Cottage Lake Creek between 2006 and 2010.

The *t*-tests were run at a significance level (α) of 0.05, which corresponds to a confidence level of 95 percent. This testing level was selected based on the data quality objectives in the project SAP (King County 2005). Two-tail critical t-values and probabilities were used in this analysis because the statistical hypotheses did not presume an upward or downward change in the mean concentrations. Rather, a change in either direction was possible.

RESULTS

Summary statistics for the data are presented in Tables 2, 3, and 4 for TP, Ortho-P, and Fecals, respectively. The tables list the minimum, maximum, mean, median, and variance of the sample data used in the analysis.

Table 2. Summary statistics for Total Phosphorus. All values in mg/l.

	DANL1		**DANL3**		**COT1**		**A707**	
	2006	**2010**	**2006**	**2010**	**2006**	**2010**	**2006**	**2010**
Mean	0.068	0.049	0.085	0.043	0.047	0.046	0.051	0.091
Median	0.057	0.043	0.053	0.040	0.039	0.035	0.040	0.055
Max	0.189	0.087	0.427	0.105	0.098	0.125	0.130	0.861
Min	0.034	0.029	0.029	0.021	0.025	0.023	0.016	0.025
Variance	0.0017	0.0101	0.0005	0.0004	0.0004	0.0008	0.0010	0.0276

Table 3. Summary statistics for Orthophosphate Phosphorus. All values in mg/l.

	DANL1		**DANL3**		**COT1**		**A707**	
	2006	**2010**	**2006**	**2010**	**2006**	**2010**	**2006**	**2010**
Mean	0.025	0.016	0.037	0.018	0.022	0.022	0.026	0.014
Median	0.022	0.014	0.024	0.018	0.021	0.018	0.003	0.006
Max	0.070	0.023	0.189	0.027	0.038	0.041	0.109	0.045
Min	0.012	0.012	0.010	0.008	0.008	0.012	0.002	0.002
Variance	0.00021	0.00002	0.00201	0.00005	0.00010	0.00007	0.0012	0.0002

Table 4. Summary statistics for Fecal Coliform bacteria. All values in cfu/100 ml.

	DANL1		DANL3		DANL9		COT1	
	2006	**2010**	**2006**	**2010**	**2006**	**2010**	**2006**	**2010**
GeoMean	244	87	211	67	55	19	130	132
Median	215	155	195	100	37	23	83	150
Max	6,700	890	18,000	3,900	2,600	250	3,700	3,400
Min	21	4	16	1	2	1	16	8
Variance	3,018,866	108,145	22,626,404	1,118,244	535,805	9,138	1,071,443	941,857

The standard Welch's *t*-test was run on the TP and Ortho-P data, which uses the arithmetic mean of the data sets in the *t*-value calculation. At the request of King County and because of the nature of bacterial data, the geometric mean was used in the *t*-value calculation for the Fecals data. Results of the *t*-tests are shown in Tables 5, 6, and 7 for TP, Ortho-P, and Fecals, respectively. The full results from the statistical analyses are presented in Appendix B.

Table 5. Summary of Welch's *t*-test results for Total Phosphorus.

Station	**Calculated t-value from data**	**Critical t-value, 2-tail**	**Probability (p-value), 2-tail**	**Conclusion at the 95% confidence level**
DANL1	1.480	2.093	0.155	Accept H_o. No difference in the means exists.
DANL3	1.540	2.145	0.146	Accept H_o. No difference in the means exists.
COT1	0.123	2.093	0.903	Accept H_o. No difference in the means exists.
A707	1.166	2.060	0.255	Accept H_o. No difference in the means exists.

Table 6. Summary of Welch's *t*-test results for Orthophosphate Phosphorus.

Station	**Calculated t-value from data**	**Critical t-value, 2-tail**	**Probability (p-value), 2-tail**	**Conclusion at the 95% confidence level**
DANL1	2.315	2.120	0.034	Reject H_o. A difference in the means exists.
DANL3	1.585	2.145	0.135	Accept H_o. No difference in the means exists.
COT1	0.035	2.064	0.972	Accept H_o. No difference in the means exists.
A707	1.596	2.026	0.119	Accept H_o. No difference in the means exists.

Table 7. Summary of Welch's *t*-test results for Fecal Coliform bacteria.

Station	**Calculated t-value from data**	**Critical t-value, 2-tail**	**Probability (p-value), 2-tail**	**Conclusion at the 95% confidence level**
DANL1	0.285	2.145	0.780	Accept H_o. No difference in the geo-means exists.
DANL3	0.110	2.145	0.914	Accept H_o. No difference in the geo-means exists.
DANL9	0.184	2.160	0.857	Accept H_o. No difference in the geo-means exists.
COT1	0.004	2.064	0.997	Accept H_o. No difference in the geo-means exists.

The results from the *t*-tests are to accept the null hypothesis for all but one of the comparisons that the mean concentrations are not statistically different at the 95 percent confidence level between 2006 and 2010. Only one comparison was statistically different at the 95 percent confidence level – Daniels Creek (DANL1) for Ortho-P – and the direction of the difference is downward. In other words, the mean in 2010 was lower than in 2006 for Ortho-P at DANL1.

The "no difference" conclusions are the same at the 90 percent confidence level, too, as can be seen by probabilities (p-values) in Tables 5, 6, and 7 that exceed 0.10. At the 85 percent confidence level, however, the comparisons of TP and Ortho-P at all stations analyzed on

Daniels Creek become significant (downward change in mean values). This means that some change in phosphorus concentrations is likely present in Daniels Creek between 2006 and 2010, but the certainty of that change is not as high as the 95 percent confidence level the project SAP was aiming to achieve. This general downward trend in phosphorus concentrations can be seen in the box-and-whisker plots in Appendix A where median values of TP and Ortho-P (the inward notch in the box portion of each plot) are slightly but notably lower in 2010 than in 2006. Also box-and-whisker plots for TP at DANL3 and for Ortho-P at DANL1 and DANL3 support the idea that a downward change in phosphorus may be present in Daniels Creek; the plots for these stations show a notably smaller range of values in 2010 than in 2006.

Also noteworthy is the comparison of phosphorus in Cottage Lake (station A707), which was significantly different at the 88 percent confidence level for Ortho-P (p-value of 0.12) and at the 74 percent confidence for TP (p-value of 0.26). As with the phosphorus results for Daniels Creek, these results for Cottage Lake indicate some change in phosphorus concentrations may be present in Cottage Lake between 2006 and 2010 but at a lower confidence level than the project SAP was aiming to achieve. Looking at the box-and-whisker plots for Ortho-P in Cottage Lake, the median is lower in 2010 than in 2006 and the range of values is smaller in 2010 than in 2006. Likewise the mean value of Ortho-P in Cottage Lake in 2010 was half of the value in 2006 (0.026 mg/l and 0.014 mg/l, respectively). Thus, the results for Cottage Lake support the idea that a downward change in the dissolved fraction of phosphorus may have occurred between 2006 and 2010, but this is not confirmed at the significance level desired. For TP in Cottage Lake, however, both the mean and median values are higher in 2010 than in 2006 and the range of values is larger in 2010 than in 2006. Although this pattern is not a statistically significant result, it may suggest an increase in TP occurred in Cottage Lake. This tentative conclusion is supported by the negative *t*-statistic (-1.166, see Appendix B) for the TP analysis at station A707, which would indicate an upward change (increase in TP concentration) if the results were considered statistically significant.

Several *t*-test results had high p-values and stand out as not significant. These include the TP and Ortho-P comparisons in Cottage Lake Creek (COT1, p-values 0.90 or higher) and all of the Fecals comparisons in Cottage Lake Creek and Daniels Creek (p-values 0.78 or higher). The box-and-whisker plots for COT1 support this idea because they show similar distributions of data for TP and Ortho-P between 2006 and 2010. Likewise, the Fecals plot for Cottage Lake Creek shows a similar distribution in 2006 as in 2010. The Fecals plots in Daniels Creek show similar medians but smaller range in 2010 at all Daniels Creek stations. These skewed distributions of Fecals data are likely the primary factor behind the highly insignificant Fecals results on Daniels Creek. This pattern indicates a downward trend may be present in Fecals concentrations in Cottage Lake Creek and Daniels Creek, but that trend may be in variance rather than in mean concentrations.

CONCLUSIONS

The conclusions from this analysis are that mean concentrations of TP and Ortho-P are not significantly different between 2006 and 2010 in Cottage Lake Creek and in Cottage Lake at the 95 percent confidence level, which was specified in the project SAP. One station on Daniels Creek had a significant difference - station DANL1 for Ortho-P - which shows a downward change in Ortho-P concentration from 2006 to 2010. Also, results comparing geometric mean

concentrations of Fecals for all locations on Cottage Lake Creek and Daniels Creek had high p-values (not statistically significant) indicating no change in Fecals concentration.

Although only one parameter at one station showed a statistically significant result in this analysis, some differences were seen at confidence levels lower than 95 percent. Results for TP and Ortho-P at some Daniels Creek stations and Ortho-P in Cottage Lake showed a significant difference (downward change in concentration) at the 85 percent confidence level. Also, the TP comparison in Cottage Lake was significant at the 74 percent confidence level, but the trend observed was upward, indicating a possible slight increase in mean TP values in Cottage Lake.

The TMDL for Cottage Lake (Ecology 2004) focuses on total phosphorus concentration during summer months. Results from this analysis indicate that TP concentrations are not significantly different for all stations considered between 2006 and 2010 at the 95 percent confidence level. The TMDL sets a target of 20 μg/l (0.020 mg/l) for the summer period. Because this analysis did not parse out data into seasonal periods but rather lumped data from all seasons together, it is not possible to say if summer TP concentrations meet the TMDL target. The annual statistics indicate mean and median TP concentrations greater than 0.020 mg/l. But further analysis is required to make this determination for the summer period.

Many factors can influence phosphorus and bacterial concentrations in Cottage Lake and its tributaries. These factors include land-use activities both generally and also during the sample collection times, the geology and soil characteristics in the Cottage Lake watershed, weather patterns and associated runoff, and seasonal mixing of the lake waters. An assessment of which factors influence phosphorus and Fecal Coliform bacterial concentrations in the Cottage Lake watershed is beyond the scope of this data analysis effort. However, some data analysis elements could be refined to provide more in-depth results. We have provided some recommendations below for what else can be done to analyze these data. These additional data analysis elements combined with knowledge of land use, geology, and management of Cottage Lake and its tributaries would very likely provide additional useful information for management considerations.

RECOMMENDATIONS

This data analysis effort was limited by a narrow scope of work, a small budget, and adherence to the statistical data quality objectives set forth in the project SAP. The analysis here should be considered a useful first step and, ideally, additional analysis should be done to address the specific concerns and targets set forth in the Cottage Lake TMDL. Given the results from this analysis, we recommend the following elements be considered as next steps to more fully analyze phosphorus and bacterial concentrations in Cottage Lake and its tributaries.

1. Transform data (probably logarithmic or power function) if necessary to confirm the assumption of a normal distribution and rerun the statistical tests. This would be especially useful for the Fecals data, which seem to have a skewed distribution.
2. Perform an analysis of variance (ANOVA) to compare 2010 to multiple years (2007, 2008, or 2009) and assess if some years show a difference in phosphorus or bacterial concentrations.

3. Complete a Type I/Type II error analysis to determine the probability of reaching an incorrect conclusion from the statistical tests.
4. Parse the data into seasonal periods to assess if summer TP concentrations meet the TMDL target of 20 μg/l.
5. Compare data from 2010 to 2004. This could only be done for creek stations since no lake data are available from 2004.
6. Analyze other chemical parameters that were determined for the samples collected, especially those parameters that can affect nutrient loading: total nitrogen, dissolved oxygen, pH, conductivity, and temperature. Ideally, dissolved iron would also be collected in a sampling program assessing nutrient loading since iron affects the uptake of nutrients by plants.
7. Separate data from storm periods and base flow periods to see if a difference exists during periods of elevated runoff.
8. Perform a non-parametric test. This is last on the list because a test such as the Mann Whitney test (parametric for the *t*-test) compares the distribution of ranks of the data and not the means. If an ANOVA (*F*-test) shows a difference in the variances of the data, then a rank test does not add much because a difference in sample variance usually indicates a difference in ranked data.

REFERENCES

King County. 2005. Daniels and Cottage Lake Creeks and Cottage Lake Water Quality Chemistry Sampling and Analysis Plan. June 7, 2005. King County Department of Natural Resources and Parks, Water and Land Resources Division. 20 pp.

Ledoux, B. 2010. Personal email communications with Beth Ledoux, Water Quality Planner, King County Department of Natural Resources and Parks, Water and Land Resources Division.

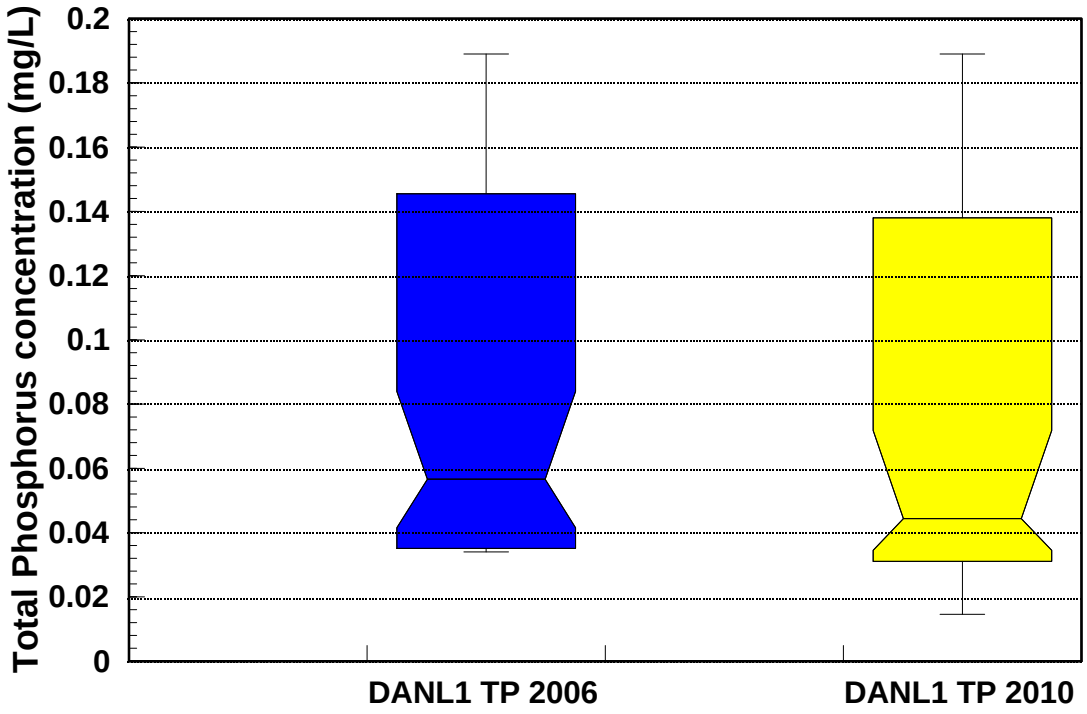
Ecology. 2004. Cottage Lake Total Phosphorus Total Maximum Daily Load: Submittal Report. June 2004. Washington State Department of Ecology. Publication no. 03-10-085.

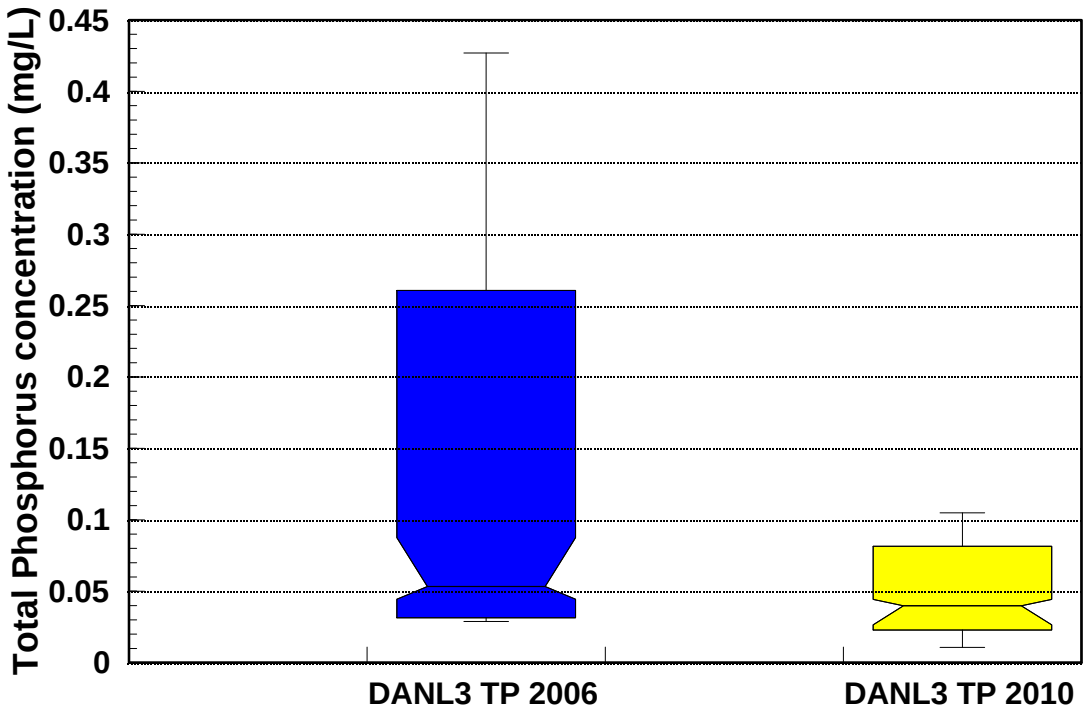
Ecology. 2007. Cottage Lake Total Phosphorus Total Maximum Daily Load: Water Quality Implementation Plan. March 2007. Washington State Department of Ecology. Publication no. 06-10-066.

Zar, Jerrold H. 1996. Biostatistical Analysis, Third Edition. Prentice Hall, Upper Saddle River, New Jersey. 662 pp.

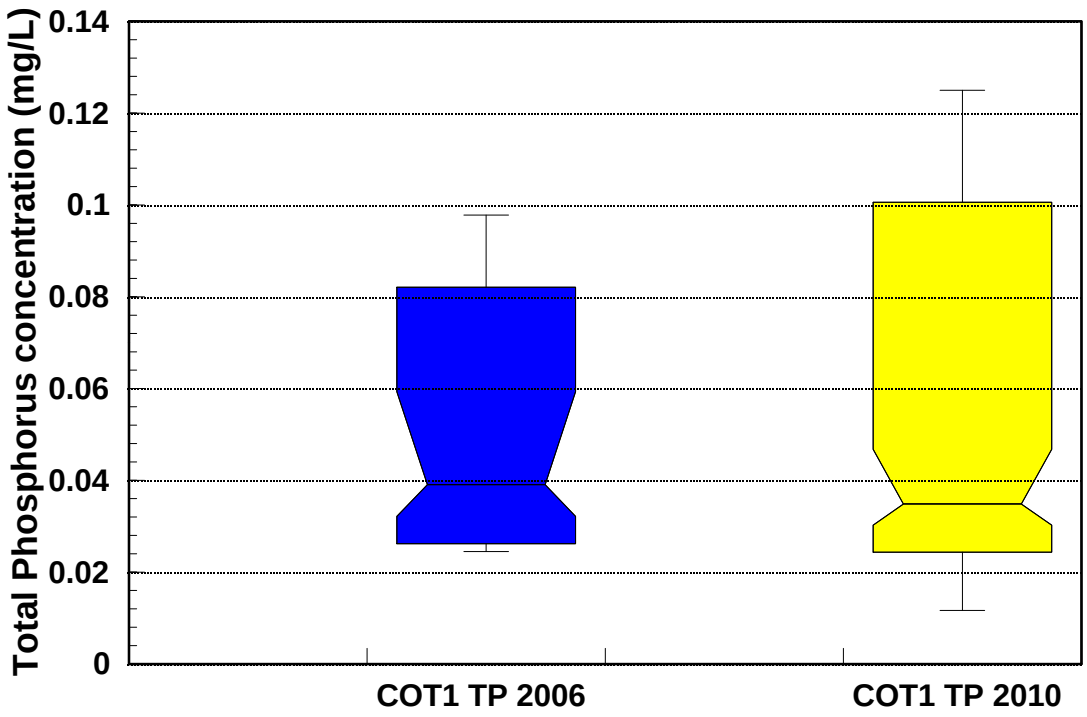
APPENDIX A – Box-and-Whisker plots

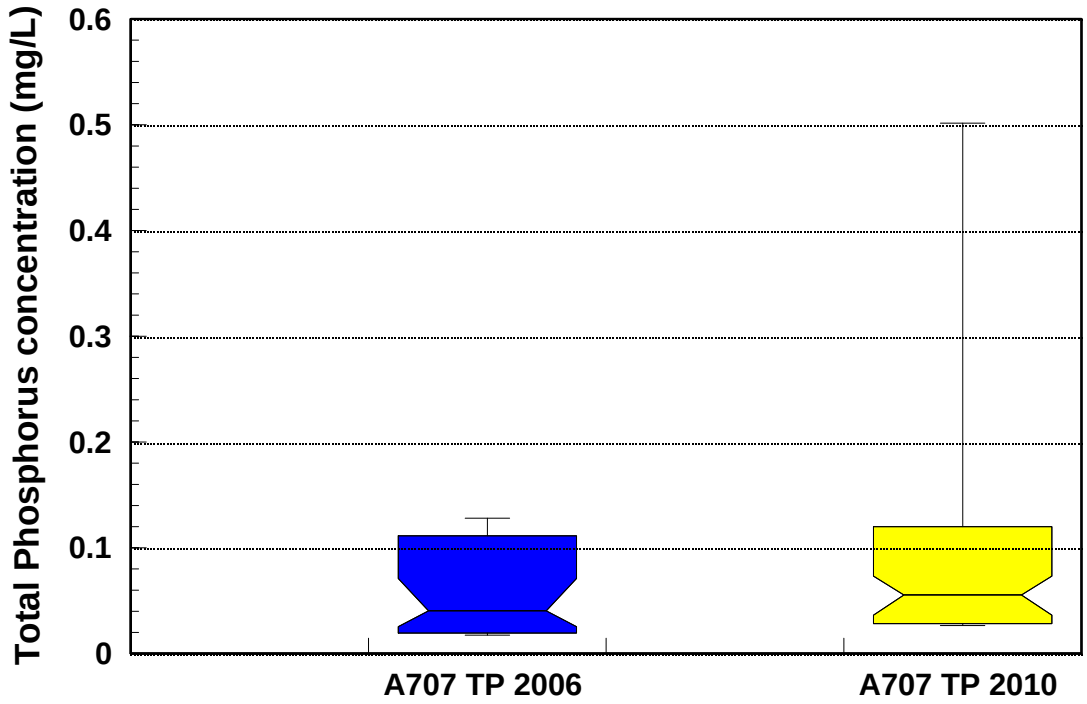
Total Phosphorus



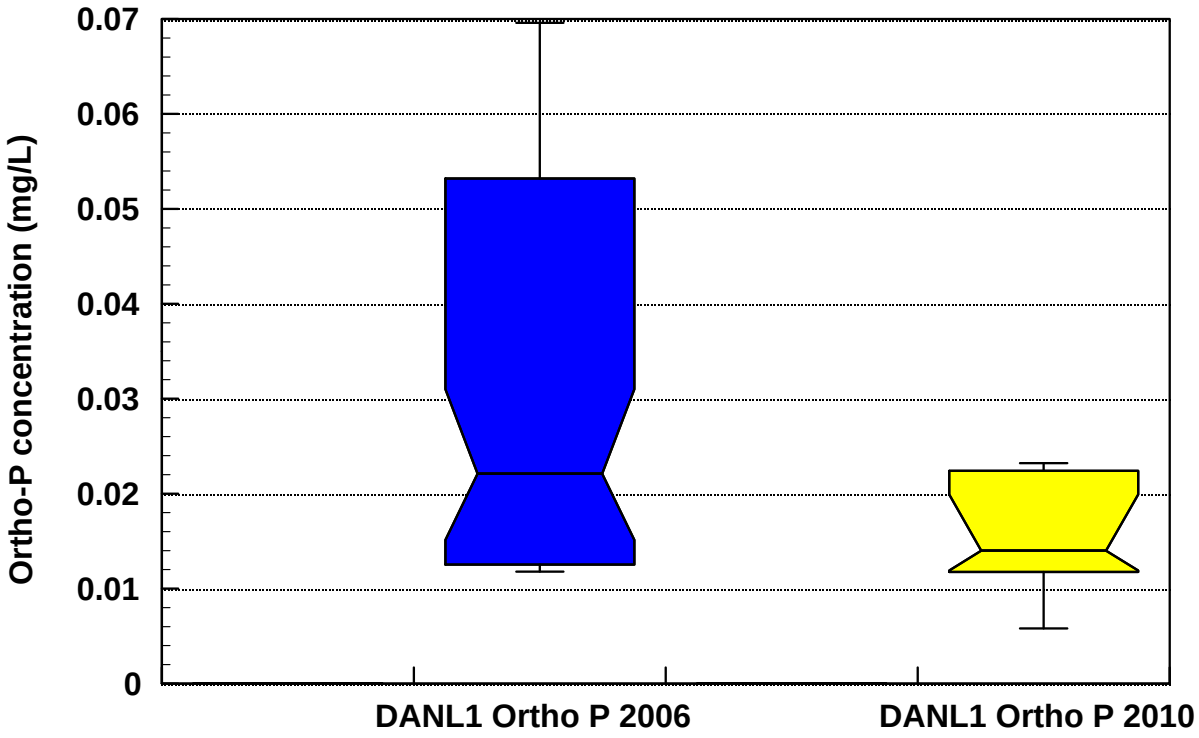


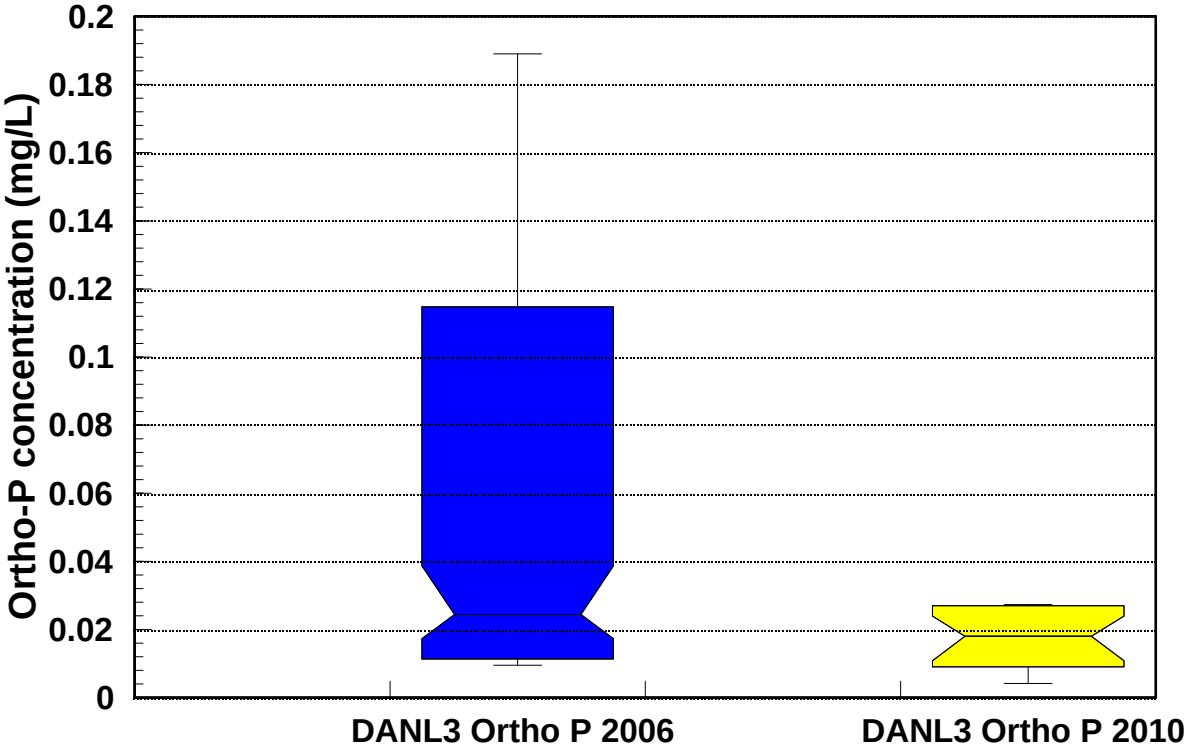
Total Phosphorus



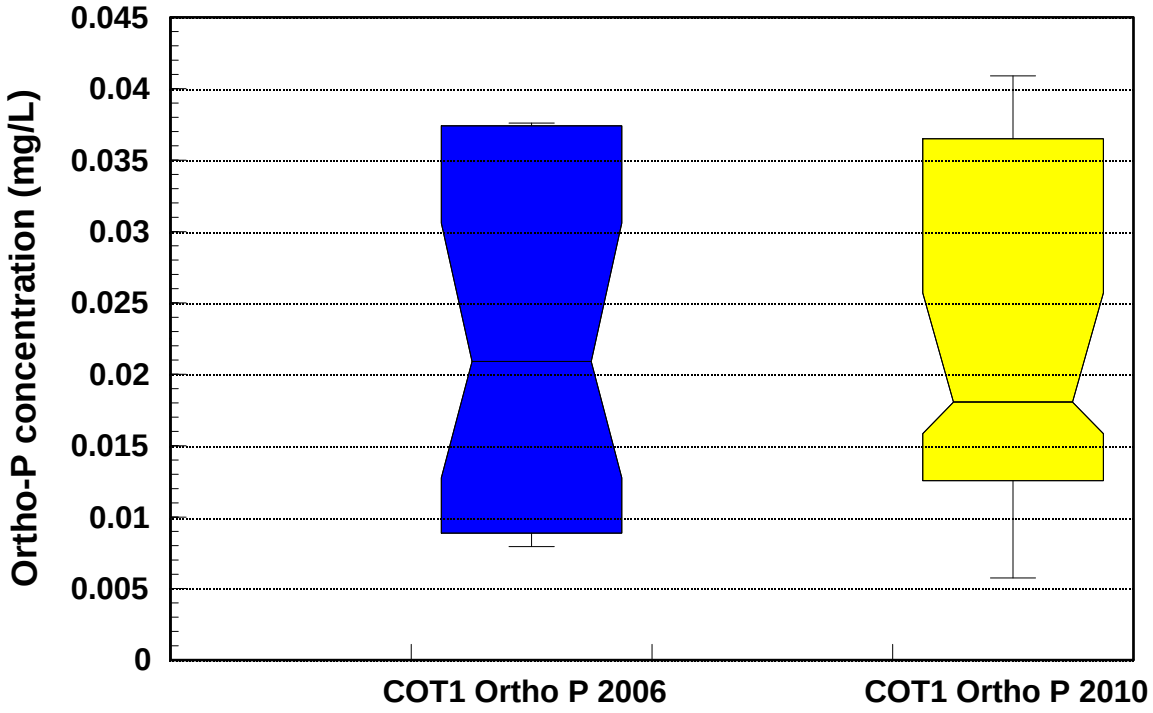


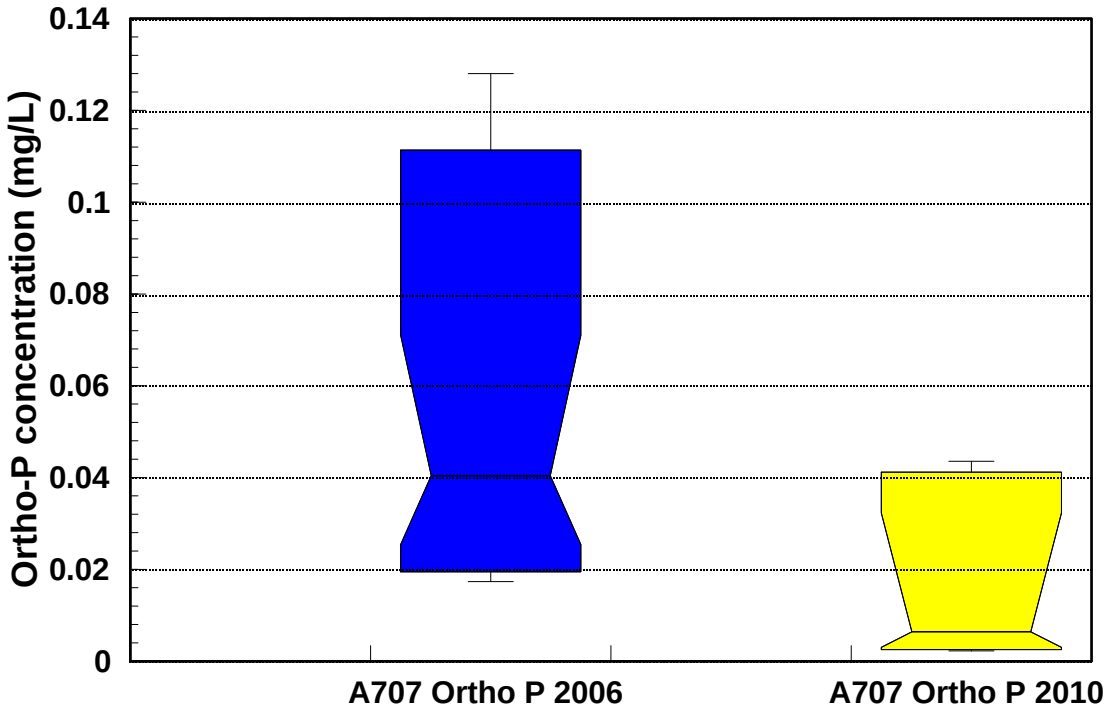
Orthophosphate Phosphorus



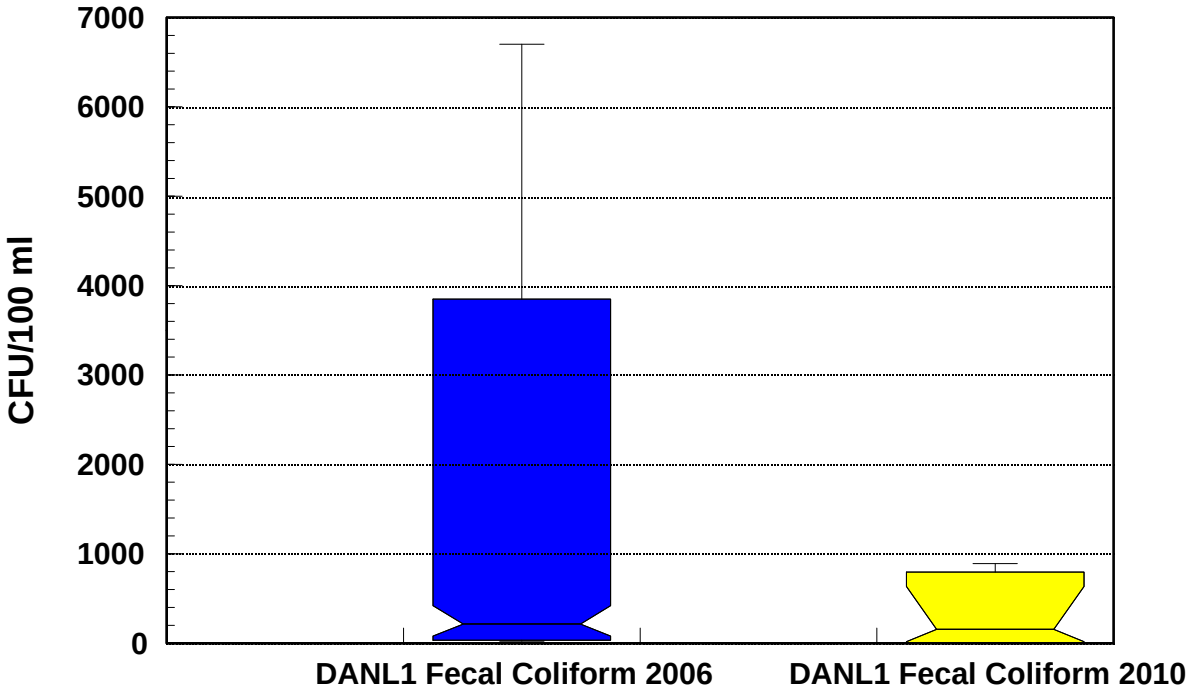


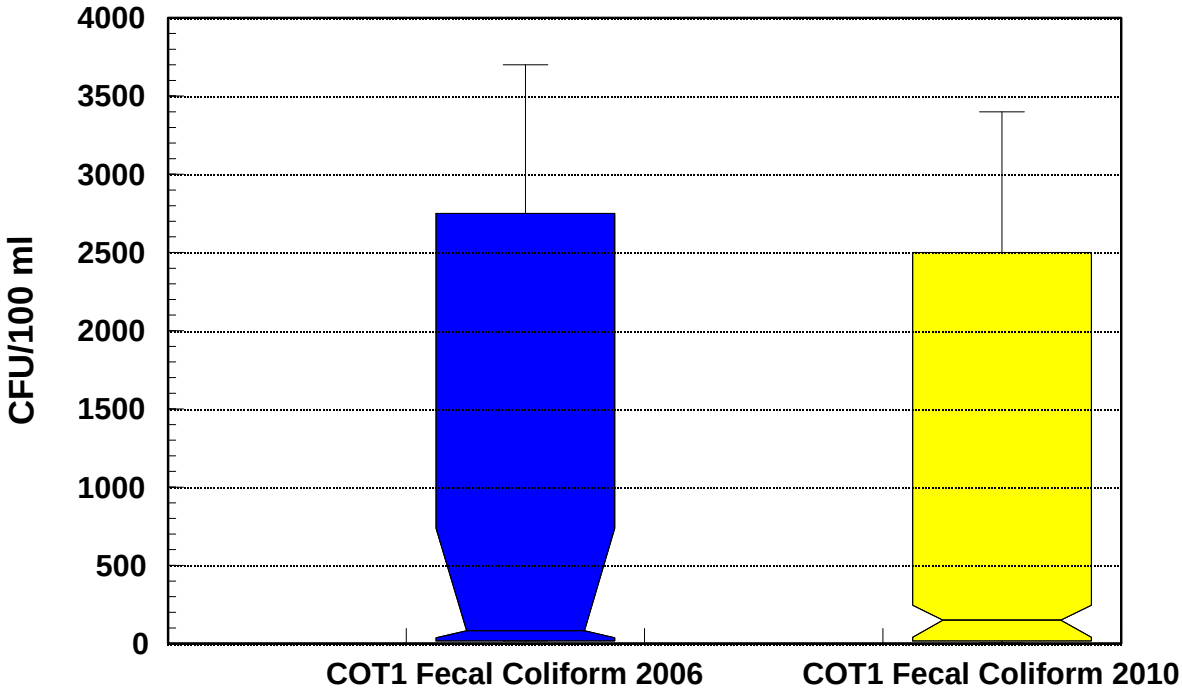
Orthophosphate Phosphorus



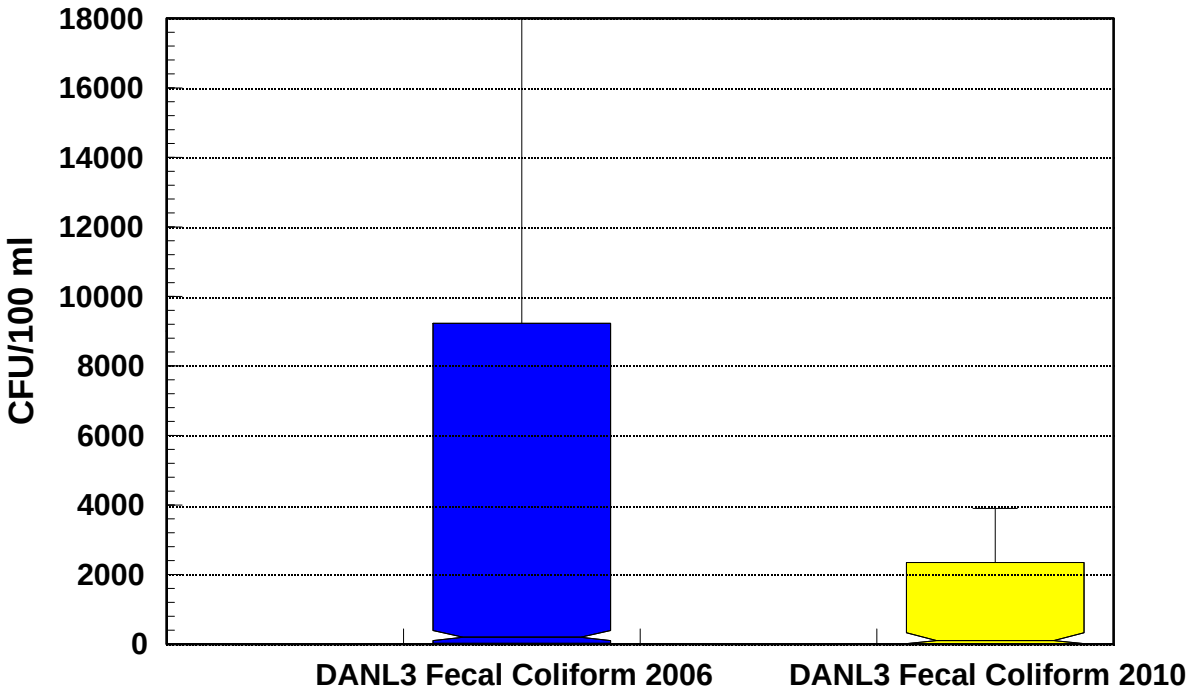


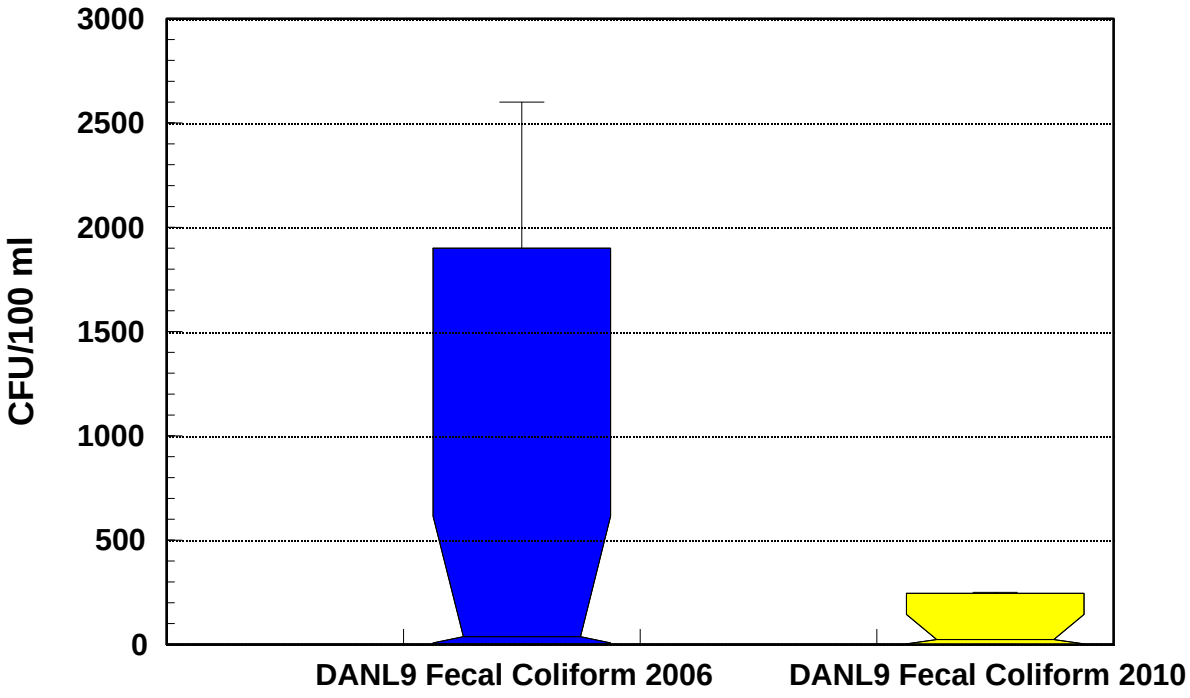
Fecal Coliform





Fecal Coliform





APPENDIX B – Welch's *t*-test results

TOTAL PHOSPHORUS

TOTAL PHOSPHORUS
DANL1
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.067789	0.049409
Variance	0.001683	0.000373
Observations	14	11
Hypothesized Mean Difference	0	
df	19	
t Stat	1.480725	
P(T<=t) one-tail	0.077536	
t Critical one-tail	1.729133	
P(T<=t) two-tail	0.155073	
t Critical two-tail	2.093024	

TOTAL PHOSPHORUS
COT1
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.046757	0.04555
Variance	0.000383	0.000825
Observations	14	12
Hypothesized Mean Difference	0	
df	19	
t Stat	0.123136	
P(T<=t) one-tail	0.451646	
t Critical one-tail	1.729133	
P(T<=t) two-tail	0.903292	
t Critical two-tail	2.093024	

TOTAL PHOSPHORUS
DANL3
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.0851	0.04255
Variance	0.01011	0.000498
Observations	14	12
Hypothesized Mean Difference	0	
df	14	
t Stat	1.539761	
P(T<=t) one-tail	0.072956	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.145912	
t Critical two-tail	2.144787	

TOTAL PHOSPHORUS
A707-1m & 2m
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.050589	0.0908
Variance	0.00103	0.027627
Observations	27	24
Hypothesized Mean Difference	0	
df	25	
t Stat	-1.166034	
P(T<=t) one-tail	0.127302	
t Critical one-tail	1.708141	
P(T<=t) two-tail	0.254605	
t Critical two-tail	2.059539	

ORTHOPHOSPHATE PHOSPHORUS

ORTHO-P
DANL1
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.025429	0.015891
Variance	0.000213	1.94E-05
Observations	14	11
Hypothesized Mean Difference	0	
df	16	
t Stat	2.314655	
P(T<=t) one-tail	0.017122	
t Critical one-tail	1.745884	
P(T<=t) two-tail	0.034244	
t Critical two-tail	2.119905	

ORTHO-P
COT1
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.021711	0.021583
Variance	9.54E-05	7.35E-05
Observations	14	12
Hypothesized Mean Difference	0	
df	24	
t Stat	0.035416	
P(T<=t) one-tail	0.486021	
t Critical one-tail	1.710882	
P(T<=t) two-tail	0.972041	
t Critical two-tail	2.063899	

ORTHO-P
DANL3
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.037164	0.017908
Variance	0.002013	4.64E-05
Observations	14	12
Hypothesized Mean Difference	0	
df	14	
t Stat	1.584725	
P(T<=t) one-tail	0.067676	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.135351	
t Critical two-tail	2.144787	

ORTHO-P
A707-1m & 2m
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.025974	0.014266
Variance	0.001171	0.00024
Observations	27	23
Hypothesized Mean Difference	0	
df	37	
t Stat	1.595957	
P(T<=t) one-tail	0.059503	
t Critical one-tail	1.687094	
P(T<=t) two-tail	0.119006	
t Critical two-tail	2.026192	

FECAL COLIFORM BACTERIA

FECALS

DANL1	2006 (x-xbar)	2006 $(x\text{-}xbar)^2$	2010 (x-xbar)	2010 $(x\text{-}xbar)^2$
	-24.225	586.837	612.539	375204.374
	6475.775	41935665.375	-55.461	3075.891
	145.775	21250.430	-77.461	6000.163
	-64.225	4124.816	62.539	3911.162
	35.775	1279.870	-82.461	6799.770
	-122.725	15061.359	-83.461	6965.691
	-203.225	41300.290	-61.461	3777.420
	-166.725	27797.135	112.539	12665.090
	-177.225	31408.604	522.539	273047.303
	-54.225	2940.321	72.539	5261.948
	5.775	33.354	572.539	327801.231
	235.775	55589.979	802.539	644069.301
	775.775	601827.273		
	155.775	24265.935		
	sum	42,763,132	sum	1,668,579
	n_1	14	n_2	12
	n_1-1	13.0	n_2-1	11.0
	sample variance, S^2_1	3,054,509	S^2_2	139,048
	Xbar1, geomean	224.225	Xbar2, geomean	87.461

d.f. numerator	52792690152		
d.f. denominator	3673912381		
d.f.	14.37	round down to	14
t-value numerator, Xbar1-Xbar2	136.764		
t-value denominator, pooled variance	479.340		
Welch's T	**0.28532**		
T-critical$_{0.05(2)14}$	**2.14479**		
p-value, 2-tail	**0.7796**		

FECALS

DANL3	2006 (x-xbar)	2006 $(x\text{-}xbar)^2$	2010 (x-xbar)	2010 $(x\text{-}xbar)^2$
	-54.225	2940.321	172.539	29769.804
	17775.775	315978186.525	702.539	493561.445
	-14.225	202.343	-27.461	754.091
	235.775	55589.979	-82.461	6799.770
	55.775	3110.881	-63.461	4027.263
	-138.225	19106.075	-84.461	7133.613
	-208.225	43357.537	-86.461	7475.456
	-114.225	13047.288	-67.461	4550.948
	-199.225	39690.492	3812.539	14535455.787
	-34.225	1171.332	192.539	37071.376
	-34.225	1171.332	12.539	157.234
	155.775	24265.935	62.539	3911.162
	-24.225	586.837	282.539	79828.447
	175.775	30896.946		
	sum	316,213,324	sum	15,210,496
	n_1	14	n_2	13
	n_1-1	13.0	n_2-1	12.0
	sample variance, S^2_1	22,586,666	S^2_2	1,170,038
	Xbar1, geomean	210.869	Xbar2, geomean	66.901

d.f. numerator	2901354285413		
d.f. denominator	2.00894E+11		
d.f.	14.44	round down to	14
t-value numerator, Xbar1-Xbar2	143.969		
t-value denominator, pooled variance	1305.119		
Welch's T	**0.11031**		
T-critical$_{0.05(2)14}$	**2.14479**		
p-value, 2-tail	**0.9137**		

FECAL COLIFORM BACTERIA

FECALS DANL9	2006	2006	2010	2010
	(x-xbar)	$(x\text{-}xbar)^2$	(x-xbar)	$(x\text{-}xbar)^2$
	205.775	42343.463	-53.461	2858.048
	2375.775	5644308.144	162.539	26419.019
	-200.225	40089.942	-77.461	6000.163
	-188.225	35428.548	-86.461	7475.456
	-217.225	47186.582	-83.461	6965.691
	-220.225	48498.931	-85.461	7303.534
	-217.225	47186.582	-86.461	7475.456
	-186.225	34679.649	-70.461	4964.713
	-222.225	49383.830	-9.461	89.505
	-211.225	44615.886	152.539	23268.233
	575.775	331517.164	-64.461	4155.184
	975.775	952137.382	122.539	15015.876
	-158.225	25035.065	-34.461	1187.541
	-14.225	202.343		
	sum	7,342,614	sum	113,178
	n_1	14	n_2	13
	n_1-1	13.0	n_2-1	12.0
	sample variance, S^2_1	524,472	S^2_2	8,706
	Xbar1, geomean	55.280	Xbar2, geomean	19.407

	d.f. numerator	1454050080	
	d.f. denominator	107993140.2	
	d.f.	13.46	round down to 13
	t-value numerator, Xbar1-Xbar2	35.873	
	t-value denominator, pooled variance	195.274	
	Welch's T	**0.18371**	
	T-critical$_{0.05(2)13}$	**2.16037**	
	p-value, 2-tail	**0.85710**	

FECALS COT1	geomean 2006	2006	2010	2010
	(x-xbar)	$(x\text{-}xbar)^2$	(x-xbar)	$(x\text{-}xbar)^2$
	-154.225	23785.267	1512.539	2287775.084
	1575.775	2483067.708	-15.461	239.034
	-182.225	33205.851	-79.461	6314.005
	-175.225	30703.705	102.539	10514.305
	-129.225	16699.030	122.539	15015.876
	-188.225	35428.548	-62.461	3901.341
	-206.225	42528.638	192.539	37071.376
	-185.225	34308.200	-34.461	1187.541
	-208.225	43357.537	3312.539	10972916.504
	-54.225	2940.321	62.539	3911.162
	-104.225	10862.794	-60.461	3655.498
	560.775	314468.906	72.539	5261.948
	3475.775	12081013.742	32.539	1058.805
	465.775	216946.604		
	sum	15,369,317	sum	13,348,822
	n_1	14	n_2	13
	n_1-1	13.0	n_2-1	12.0
	sample variance, S^2_1	1,097,808	S^2_2	1,026,832
	Xbar1, geomean	130.313	Xbar2, geomean	131.759

	d.f. numerator	24775388710	
	d.f. denominator	992905521.4	
	d.f.	24.95	round down to 24
	t-value numerator, Xbar1-Xbar2	1.445	
	t-value denominator, pooled variance	396.739	
	Welch's T	**0.00364**	
	T-critical$_{0.05(2)24}$	**2.06390**	
	p-value, 2-tail	**0.9971**	

DANIEL'S AND COTTAGE LAKE CREEKS AND COTTAGE LAKE

WATER QUALITY CHEMISTRY

SAMPLING AND ANALYSIS PLAN

Prepared by the

Water and Land Resources Division

King County Department of Natural Resources and Parks

June 7, 2005

NAME OF PROJECT: Cottage Lake Phosphorus Reduction Plan

PROJECT NUMBER: **421195AM**

SAP PREPARED BY: Beth Cullen

King County Department of Natural Resources and Parks

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1. PROJECT BACKGROUND

1.1. Study Support

The Cottage Lake Phosphorus Reduction project is designed to achieve compliance with the Total Maximum Daily Load (TMDL) for phosphorus in Cottage Lake. The TMDL was set forward by the Washington State Department of Ecology (State) and approved by the Environmental Protection Agency (EPA). To try and meet the terms of the TMDL it is critical to understand whether the phosphorus pollution is from external or internal sources. If the majority of the phosphorus load is from the inlet streams, Cottage Lake and Daniels Creek, sources of the pollution must be pinpointed i.e. septic systems, hobby farms, residential or industrial. By understanding the source of pollution, proper management plans will be constructed to meet and come in compliance with the phosphorus TMDL and eventually lead to the delisting of Cottage Lake from the Federal Clean Water Act 303(d) list of impaired water bodies.

In addition to understanding the phosphorus load in the system, fecal coliform pollution will also be monitored. Historical records exist of high fecal coliform counts in the Cottage Lake system and it is imperative to monitor this trend to ensure that it is not a threat to public health.

Parameters to be measured for the duration of this project include:

- Cottage Lake – The field parameters include secchi depth, temperature, dissolved oxygen, pH, and conductivity. Lab parameters include orthophosphate, total nitrogen, total phosphorus, nitrate, ammonia, total suspended solids, fecal coliform, chlorophyll *a,* pheophytin and phytoplankton.

- Daniel and Cottage Lake Creeks – Field parameters include temperature, flow, pH, dissolved oxygen, and conductivity. The lab will analyze total phosphorus, orthophosphate, fecal coliform and total suspended solids.

- Storm Samples – total suspended solids, total phosphorus, orthophosphate and fecal coliform.

All data collected will be compared with historical data in Cottage Lake and its tributaries. Data collected during this project will be compared to the data used to develop the Cottage Lake Management Plan (years collected, 1994-1996) and the TMDL. Tributary data collected in 2003-2004 will also be used for comparison.

1.2. Reference to regulatory program

Data from this sampling effort will be used to support the TMDL regulation and delisting Cottage Lake from the Federal Clean Water Act 303(d) list of impaired water bodies.

1.3. Project Goals and Objectives

The goal of this project is to understand the sources of phosphorus and fecal coliform pollution the Cottage Lake system. We will also determine if a majority of phosphorus pollution is from internal or external loading. This data will help us design strategies to reduce pollution in the system in attempts to come into compliance with the TMDL.

2. STUDY DESIGN

2.1. Statistical Data Quality Objectives

2.1.1. Study Questions to be answered

To establish if the majority of phosphorus is entering the lake through tributaries or if the high levels of phosphorus are due to internal cycling within Cottage Lake. We will determine if there is a public health threat due to elevated levels of fecal coliform in the system.

2.1.2. Tools to be used in analyzing the data to provide answers

The data will be analyzed using paired t-tests, comparing current data with historical data collected on the lake and streams.

2.1.3. Estimated confidence level and power in the statistical tests

The established confidence level will be 95%.

2.1.4. Sampling strategy to obtain representativeness

Some samples will be collected from sites based on historical sampling locations and will be collected at comparable intervals and times of year. New stations will be established to understand how the concentrations of certain parameters change throughout the tributaries and then in the lake.

2.1.5 Storm Samples

Storm samples will be collected three times during the year. Storm criteria will be at least one inch of precipitation in 24 hours, preferably with three antecedent dry days prior to the storm.

2.2. Spatial data quality objectives

2.2.1. Station locations

<u>Daniels Creek</u>

Seven stations will be monitored monthly for the first year on Daniels Creek and then reduced to five stations (monthly) in the second and third years. The first year will mirror the sampling completed in 1994-1996 and 2003-2004. The first year of monitoring will show the pattern of water quality through the Daniels Creek drainage. Once this is understood, the number will be reduced to the five key stations in the drainage that capture the movement of the different parameters sampled. The stations will begin at the mouth of the creek and then be sampled at established stations upstream. The stations begin at the mouth at DANL0, then DANL1, DANL2, DANL3, DANL6, DANL9, and a new station, DANL13, close to the King-

Snohomish County border (if access is provided). During each water year, three storm events will also be collected at these 7 stations. See Appendix A for a map of monitoring stations.

Cottage Lake Creek

Cottage Lake Creek will be sampled monthly at potentially three stations for the full duration of this project. The first station is COT1 at the mouth of Cottage Lake Creek into Cottage Lake Park. The second station station, COT2, is located along the Woodinville-Duvall Road. Upstream from COT2 and near the elementary school is COT5. If access to DANL13 is not granted, COT5 will be monitored. Three storm samples will be collected at these stations each water year. See Appendix A for a map of monitoring stations.

Cottage Lake

Two stations in Cottage Lake will be sampled monthly for three years. The mid-lake station, A707, will be sampled at four depths using a VanDorn vertical sampler. The depths will be surface (1m), 2, 4, and 6 meters. The second site (A707D) will be sampled close to the inlet of Daniels Creek with a van Dorn and will be sampled at the surface (1 meter) and 1 meter from the bottom. Three storm samples will be collected at the two stations at four depths 1m, 2m, 4m, and 6m on each station. See Appendix A for a map of monitoring stations.

Stations may be changed mid-project if analysis of the incoming data suggests that different stations would give more pertinent information in meeting the goals of the program.

TABLE 1: Station Names and Coordinates

Locator	Latitude	Longitude
A707	47 45 10.4026	-122 05 16.1993
A707D	47 45 18.8015	-122 05 23.0162
COT1	47 45 18.489	-122 05 10.8834
COT2	47 45 25.8636	-122 05 2.68368
COT5	47 45 47.2161	-122 04 54.1582
DANL0	47 45 23.2142	-122 05 27.3119
DANL1	47 45 27.6268	-122 05 31.6077
DANL2	47 45 35.5966	-122 05 50.3214
DANL3	47 45 41.239	-122 06 5.00346
DANL6	47 45 46.9055	-122 06 16.1741

DANL9	47 46 8.00054	-122 06 17.7935
DANL13	47 46 32.2793	-122 06 26.7695

2.2.2. Spatial resolution

2.2.2.1. Method for coordinate measurements

All stations will be identified and recorded with a hand-held GPS unit.

2.2.3. Locator precision needs

When applicable, all stations will be matched as carefully as possible to the original station coordinates. Given the changes in sampling stations over time, an exact match may be impossible, but a location will be established that will be satisfactory for our monitoring needs and purposes of comparison. For each station, old and new, a narrative detailing visual identifiers will be included with the coordinates to help locate the stations for future field work.

2.3. Laboratory data quality objectives

2.3.1. Precision and Bias

Laboratory precision will be assessed using laboratory duplicates. When both sample results exceed the RDL (reporting detection limit) the RPD (relative percent difference) should be less than 25 %. No criteria are presented for duplicate results which are below the RDL, as these RPD are provided for informational purposes only. For organics parameters the MS/MSD recoveries as well as the MS/MSD non-spike recoveries will be used to assess precision.

Bias is an indicator of the accuracy of analytical data. For this project, laboratory control samples or blank spikes, whichever are available, will be used to assess bias. Results should be within 20% of the true value or within the criteria provided with the purchase of the control sample.

Bias will also be assessed by the evaluation of method blank data. Analytical results for method blanks should be less than the MDL (method detection limit).

The use of matrix spike recovery data will provide additional information regarding method performance on actual samples. The laboratory will use professional judgment regarding assessment of data quality and any subsequent action taken as a result of matrix spike recoveries.

For microbiology parameters, the precision criterion, as described in Standard Methods 9020B.4. will be used to determine precision acceptance. Performance of the precision criterion test requires 15 sample pairs and will be accomplished using historical paired samples of similar matrix.

2.3.2. Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at the sampling point, or an environmental condition. Water chemistry samples will be collected from stations with pre-selected locations to represent specific objectives.

2.3.3. Completeness

Completeness is defined as the total number of samples for which acceptable analytical data are generated, compared to the total number of samples submitted for analysis. Adhering to standardized sampling and analytical protocols will aid in providing a complete set of data for this project. The goal for completeness is 100%. If 100% completeness is not achieved, the project manager will evaluate whether the DQOs can still be achieved or if additional samples need to be collected and analyzed.

2.3.4. Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. This goal is achieved through using standard techniques to collect and analyze representative samples, along with standardized data validation and reporting procedures. By following the guidance of this SAP, the goal of comparability will be achieved.

3. PROJECT MANAGEMENT

3.1. Roles and responsibilities

Beth Cullen, Lake Stewardship Water Quality Planner/ Project Manager I, will be the project manager and will be in charge of coordinating, collecting, and delivering samples; coordinating project team members; and writing up the final project report.

Michael Murphy, an Environmental Scientist with the King County Lake Stewardship Program, will provide field support and technical assistance.

Sally Abella Program Manger of the Lake Stewardship program will supervise the work and offer technical advice and support.

Benjamin Budka, Lab Project Manager, will be responsible for the preparation of sample containers, labels, field sheets, and the coordination of lab analysis and the compilation of the lab data report to Beth Cullen.

3.2. Time line/ project schedule

Sampling will begin in the second week of July and continue once a month for three years. The first sampling date will always try to occur in the second week of the month for the duration of the project, to December 2008.

3.3. Project deliverables

Laboratory results will be reported in an excel spreadsheet. If needed, the lab project manager will write a brief case narrative to describe any significant sampling issues or QC anomalies reported from lab units. Otherwise, the lab QC reports will suffice as a complete data package along with the excel data report. Reports will be transmitted electronically to Beth Cullen and Sally Abella.

At the end of the project, a report will be written describing the project goals and objectives, methodology, results, and conclusions. . It is anticipated that a completed product will be delivered at the end of the fourth quarter of 2008.

4. FIELD METHODS AND TECHNIQUES

4.1. Station positioning methods

All field stations will be located using historical field notes, maps, and the coordinates found in Table 1. The stations will be recorded using a GPS unit and further notes will be made on visual identifiers to increase the precision with which the stations can be located in the future.

4.2. Field Measurement QC procedures

Field measurements will be collected with a Hydrolab multi-parameter sonde.

4.2.1 Calibration

Calibration is typically done in the lab in the following order; dissolved oxygen, conductivity, and pH. Depth sensor verification is done in the field at the first site of the day. (Manufacturer recommends this order – lowest to highest conductivity reading to minimize erroneous readings due to cross contamination.) Calibration must be done within 24 hours of the start of field analysis.

4.2.2 Dissolved Oxygen

Before beginning, check the condition of the DO membrane. It should be free of bubbles, tears and creases. If not, see section 13.0- Preventative Maintenance. Remember after changing the membrane the probe must soak in tap water 24 hours before calibrating. If the membrane is ok, then proceed further.

With the multiprobe oriented so that the sensors are pointed upward, partially fill the open-ended calibration cup with tap water or conductivity calibration standard (11.2.1.3 or 11.2.1.2) slightly below the level of the o-ring used to secure the DO electrode membrane. Blot any water droplets from the membrane surface and loosely cover the open top of the calibration cup with the cap. Allow the DO response to stabilize (about 15 minutes) and access the calibration menu to update the calibration. Press *Setup/Cal, Calibration, Sonde, DO% :Sat*. Enter the barometric pressure in mm Hg using the digital barometer. Press *Done*. Following calibration, record the % saturation displayed by the meter in the calibration logbook as the initial calibration check. The % saturation displayed should be within 1% of the set point (100%).

4.2.3 Conductivity

Rinse the sensors several times with RO water with the calibration cup installed. Then rinse the sensors twice more with a small portion of the conductivity standard appropriate for the expected field conditions. Use 6667 umoh/cm (11.2.1.2) for salt water environments and 73.9 umoh/cm (11.2.1.3) for fresh water environments. Discard these rinsates and fill the calibration cup with fresh conductivity calibration standard. Once the conductivity reading has stabilized, access the Calibrate menu by pressing *Setup/Cal, Calibration, Sonde,* and *spCond : uS/cm*. Use *mS/cm* if calibrating for salt water. Enter the appropriate concentration (usually 6667 or 73.9) of the calibration standard and hit the *Done* key to calibrate. Record the measured conductivity of the calibration standard in the calibration logbook. Rinse the calibration cup with RO water 2 times and fill with the appropriate Check Standard (either 11.2.2.2 or 11.2.2.3). The response must be within 10% of the expected value or the sonde must be recalibrated and rechecked with fresh solutions. Record the measured value of the Check Standard in the calibration logbook.

4.2.4 pH

Rinse the sensors with a small portion of the pH 7 buffer (11.1.1.1) with the calibration cup installed. Fill the cup to above both electrodes with fresh pH 7 buffer and allow the response to stabilize. Access the calibration menu by pressing *Setup/Cal, Calibrate, Sonde,* and *pH :Units*. Enter the appropriate information and press *Done*. Once calibrated, record the pH response of the pH 7 buffer, dispose of the buffer and rinse the sensors with tap water. Then rinse the probe 2 times with a small portion of a second buffer (pH 10 (11.1.1.2) or pH 4 (11.1.1.3)) which will best bracket the expected field responses. Fill the cup with the second buffer and allow the response to stabilize. Access the calibration menu and enter the appropriate information. Once calibrated, record the pH response of this second calibration buffer, dispose of the buffer and rinse the sensors well with tap water. Rinse the sensors 2 more times with a small portion of the pH Check Standard (11.1.2). Fill the cup with this buffer and allow the response to stabilize. The response must be within +/- 0.2 pH units of the true value (pH 6.86) or the sonde must be recalibrated and rechecked with fresh solutions. Record the measured value of the check standard in the calibration logbook.

4.2.5 Temperature

Temperature probe calibration is factory-set and requires no daily re-calibration. Annually, the calibration must be verified as described in the QC section 9.3.

4.2.6 Depth

The Hydrolab Sonde has a depth sensor and the user can check the display to raise or lower the probe to the desired depth. If sensor data is to be collected at a particular depth and the meter's depth reading is used to confirm the depth of the probe, the calibration of the depth sensor must be checked. The user should check that the reading above the water reads zero, and that immersion at one meter yields a correct reading. The sonde should be immersed such that the base of the probe is at one meter. A measuring device such as a marked Secchi disk line can be used to determine the accuracy. If the Hydrolab sonde needs recalibration, the

manufacturer suggests holding the unit in the air and then calibrating the unit to read zero. The QC sheet should reflect the actions of the user. The values of the depth readings used to confirm calibration should be recorded.

4.2.7 Internal Clock Calibration Check

Verify the Data Logger's internal clock coincides with within +/- 30 seconds of the lab atomic clock (see 7.6). The internal clock is reset by pressing *Setup/Cal, Set-up*. Arrow down to *Clock* and press the *Select* button. Verify and/or change the date first *(MMDDYY)* and press *Done.* Change Time *(HHMMSS)* and press *Done* when the atomic clock time agrees with the internal clock time.

4.3 Routine Use - Field Measurements

See KCEL SOPs # 02-02-002 and # 02-02-003 for measurements made in marine and freshwater systems.

Remove the calibration cup and install the weighted sensor guard. When deploying the Hydrolab in waters flowing at less than one foot per second or 0.25 meters per second, such as a lake, activate the stirrer. This provides adequate flow for reliable DO readings. The stirrer is activated by pressing *Setup/Cal, Setup, Sonde*. Arrow down to *Circltr* and press the *Select* button. Arrow to 1, press *Select, Done* and the circulator will start. Remember the circulator should be turned off after you are done sampling, during QC work and during streams sampling.

Measurements are recorded by first entering the appropriate annotation (locator name) for the specific sampling location (example: 0852). Once the annotation is entered, the probe is adjusted to the correct depth using the depth sensor (Major Lakes project) or in the appropriate location within the stream. Allow the probe to equilibrate (stabilize). Equilibration occurs when the instrument has stabilized enough so that the readings no longer change in a linear direction over the course of a short period of time, such as 20-30 seconds. Although equilibration is subjective, experienced operators can quickly and efficiently recognize equilibration. The *store* key is then pressed to record the data. The locator annotation must be entered for each unique location (Multiple depths under one locator annotation are allowed). A macro is available for downloading the electronic Hydrolab data directly in to LIMS, so a unique LIMS number corresponds to the depth automatically, without making annotations in the field. For field duplicates, annotate the locator name including the word DUP.

The following sequence is to be followed for annotating and storing a typical data point; *Annotate* (write locator code), *Enter* (stores annotation) then *Store* (to store meter readings). Press *Files, Surveyor 4, Annotate (Select),* choose the correct file, then *Select*. Enter the appropriate locator or sample number using the arrow keys and *Select*. Press *Done* when completed. Press *Go Back* twice. When the instrument has equilibrated, press *Store*. Select the appropriate file to store the data to and press *Select*. For some projects, the readings are recorded on the laboratory fieldsheets. If this is to be done, the analyst should use (retrieve)

the data that is logged to the hydrolab rather than writing down real-time data. This will eliminate any discrepancies between the fieldsheet data and the hydrolab electronic data.

Note that the stored Major Lakes hydrolab data will be downloaded into LIMS. Streams data are recorded directly on to fieldsheets, then manually entered in to LIMS.

The probe must be capped during the time between the last field measurement and arrival at the lab and must be stored with sufficient ambient water in the cap to maintain high humidity but not cover the individual probes.

5.0 QA/QC REQUIREMENTS

5.1 Post-Deployment Calibration QC (End Check)

Calibration QC requirements for typical operation involve determination of post-deployment calibration drift for the parameters of interest. Calibration drift is determined by measuring the check standard solution at the conclusion of the field measurements. This check must be done within 12 hours of the last field measurement. The post-deployment checks must be done in the same order used for initial calibration and must be done before any maintenance or calibrations are performed.

5.1.1 DO Post-Deployment Calibration Check

Set up the sonde as described in 8.2.1. Measure the % DO in the saturated air and record the value.

5.1.2 Conductivity Post-Deployment Calibration Check

Immediately after the DO check, fill the calibration cup with the Conductivity calibration check standard (11.2.2.2 or 11.2.2.3) and record the measured value.

5.1.3 pH Post-Deployment Calibration Check

Immediately after the Conductivity check, fill the calibration cup with the pH calibration check standard (11.1.2) and record the measured value.

If any parameter falls outside the acceptance limits shown below, the field data collected with the sonde may be qualified. See QA Manual.

5. PARAMETER	**Calibration Drift End Check**
Dissolved Oxygen	± 4 %
Temperature	see below
Conductivity	± 10 %
pH	± 0.2 pH units

5.2 Field QC

QC for field measurements is typically limited to measuring precision by collection of replicate (FREP) and duplicate (FDUP) field measurements. Replicates are done at a minimum frequency of 5% of measurements or once per day. A field replicate is defined as a separate in-situ measurement made following all procedures typically done between individual samples. The probe would typically be removed from the water body then returned to the same depth and position used in the original measurement. Field measurement duplicates are defined as two sequential measurements made on a portion of the sample collected in a bucket or other container (Turn circulator on or swirl probe slowly.) Again, remove the probe from the bucket/water between readings. If the measurement is not typically done in a bucket or similar container, the field duplicate values are to be used only for QC purposes. Field duplicates will typically be performed immediately following the field replicates.

To meet project requirements, checks using calibration check standards may also be performed in the field. A pH calibration check standard (11.1.2) and a conductivity calibration check standard (11.2.2.2 or 11.2.2.3) may be taken into the field for each sampling run. The calibration checks should be analyzed at the same frequency as the field replicates and duplicates (a minimum frequency of 5% of measurements or once per day)

The following table describes the acceptance limits for field duplicates and calibration check standards. Since field replicates may be affected by changing field conditions rather than instrument problems, no acceptance limits have been defined.

Parameter	Duplicate Samples	Field Calibration Check Standards
Dissolved Oxygen	RPD ≤ 20%	Not applicable
Temperature	± 0.3 ^{o}C	Not applicable
Conductivity	RPD ≤ 10%	± 10 %
pH	± 0.2 pH units	± 0.2 pH units

RPD = Relative Percent Difference = $\mathbf{100 \times [(r_1 - r_2)] / ((r_1 + r_2)/2)}$

where r_1 = result 1 r_2 = result 2

5.3 Temperature Calibration Checks

Temperature probe calibration is confirmed at least annually with a side-by side comparison of the probe response at two separate temperatures to a NIST-traceable thermometer. The probes and NIST-traceable thermometer is placed in a barrel of water that was allowed to equilibrate for 24 hours at room temperature (note that this is the same water used to calibrate

the CTD DO probe). Once the probe response has stabilized (no longer than 10 minutes), the probe and thermometer readings are recorded in the calibration logbook. The probes and NIST-traceable thermometer are then placed in a beaker of RO water that is stored in the walk-in cooler at 4 ^{o} C. Once the probe response has stabilized (but no longer than 10 minutes), the probe and thermometer readings are recorded in the calibration logbook. For both temperature points, the probe response must be within ± 0.2 ^{o} C of the measured response of the NIST-traceable thermometer. If not, the meter should be returned to the manufacturer or other appropriate corrective action taken.

5.4 Corrective Action

If calibration verification or precision of duplicate field measurements do not meet specifications, these QC measurements should be immediately repeated. Calibration failures that are detected in the field may be corrected by re-calibrating then repeating the calibration verification. If this second verification or duplicate fails, the instrument should not be used for field measurements until the problem is fixed and acceptable performance has been verified. If QC failures are observed, lab analysis may also be used in place of field measurements. It may be necessary to flag the data or repeat the measurements with a properly functioning meter if other corrective actions cannot be performed.

Changing field conditions rather than a malfunction of the field meter may affect replicate field measurements. No corrective actions will be based on field replicates when acceptable field duplicates are observed. Significant changes in barometric pressure may affect the post-calibration values. This change should be documented.

6. SAMPLE COLLECTION

6.1. Sampling Equipment

A Hydrolab multi-parameter sonde will be used to collect field data including dissolved oxygen, pH, temperature, and conductivity. A secchi disk will be used to determine water clarity and a van Dorn sampler will collect water quality samples at various depths on Cottage Lake. The King County Environmental Lab will supply the labels, field sheets and sample bottles for all the water quality samples.

6.2. Decontamination procedures

For stream samples, sample bottles except for fecal coliform bacteria will be opened and rinsed three times with the creek water. The sample bottles will be dipped into the stream at a representative location within the channel, capped immediately after collection and placed in an ice-filled cooler.

For lake profile samples, the van Dorn vertical sampler will be rinsed at the appropriate depth. Bottles used for the lake samples will be triple rinsed with water from the appropriate depth and then filled with water from the vertical sampler, capped immediately after collection and placed in an ice-filled cooler.

6.3. Sample storage containers and holding times

All samples will be stored in an ice-filled cooler and will be delivered to the lab immediately after sample collection. Samples will be maintained in temperature-regulated refrigerators or in coolers on ice and stored at 4°C.

Table 2 shows sample bottle requirements and preservatives. Sample containers will be provided by the King County Environmental Laboratory.

Table 2. Container, Preservation and Holding Time Requirements

Parameter	Matrix	Container	Preservation	Holding Time
Ammonia	Fresh water	125-mL HDPE, CWM	4°C[1,2,3]	1 Day
Orthophosphorus	*Fresh water*	125-mL HDPE, CWM	4°C[1,3]	1 Day
Total Nitrogen	Fresh water	125-mL HDPE, CWM	4°C[2 4]	2 Days
Total Phosphorus	Fresh water	125-mL HDPE, CWM	4°C[2, 4]	2 Days
Nitrate	Fresh water	125-mL HDPE, CWM	4°C[1,2,3]	1 Day
Total Suspended Solids	Fresh water	1-L HDPE, CWM	4°C	7 Days
Chlorophyll *a*	Fresh water	1-L HDPE, AWM	4°C[1,5]	1 Day
Pheophytin *a*	Fresh water	1-L HDPE, AWM	4°C[1,5]	1 Day
Phytoplankton	Fresh water	125-mL HDPE, CWM		
Fecal Coliform	Fresh water	Sterile 500-mL PP	Refrigerate at 4°C	24 hours

HDPE – High density polyethylene; CWM – Clear wide mouth; PP – Polypropylene

1: Must be filtered through 0.45 micron filter ASAP or within 1 day from collection

2: Samples may be preserved with H2SO4 and the pH adjusted to <2. Maximum holding time for acid preserved samples is 28 days. Filtered samples must be either analyzed or preserved within 2 days from collection.

3: Filtered samples may also be preserved by freezing at -20°C. Maximum holding time for freezing is 14 days. Filtered aliquots must be frozen immediately following filtration.

4: Samples may also be preserved by freezing at –20 °C. Maximum holding time for freezing is 28 days.

5: Following filtration, the filters may be stored in acetone in the freezer for up to 28 days..

6.4. Delivery of samples to the lab if applicable

All samples, except for phytoplankton, will be delivered to the King County Environmental Lab during normal lab business hours and immediately after sample collection. Weekend sampling is not expected for this project.

6.5. Field documentation and logbook procedures

The field parameters will be documented on field sheets prepared by the lab project manager. Water quality samples delivered to the King County Environmental Laboratory will be logged in and will receive a unique sample number.

6.6. COC procedures

Chain-of-custody (COC) will commence at the time that each sample is collected. While in the field, all samples will be under direct possession and control of King County field staff. For chain-of-custody purposes, the field vehicle will be considered a "controlled area." All sample information will be recorded on the COC field sheet. This form will be completed in the field and will accompany all samples during transport and delivery to the laboratory. Upon arrival at the King County Environmental Laboratory, the sample delivery person will relinquish all samples to the sample manager. The date and time of sample delivery will be recorded and both parties will then sign off in the appropriate sections on the COC field sheet. Once completed, original COC field sheets will be archived in the project file.

7. ANALYSIS

7.1. Method and detection limit requirements

7.1.1. Conventional & Nutrient Analyses and Detection Limits

Conventional analyses, analytical methods, and associated detection limits are summarized in Table 3. All conventional analyses will be performed at the King County Environmental Laboratory. Subcontracting may be necessary, depending on in-house capacity.

Table 3 Conventional & Nutrient Analyses:

Analysis	Method	MDL (mg/L)	RDL (mg/L)	Units
Ammonia Nitrogen	SM 4500-NH_3-G	0.010	0.020	mg/L
Nitrate Nitrogen	SM4500-NO3-F	0.02	0.04	mg/L
Orthophosphate	SM 4500-P-F	0.002	0.005	mg/L
Total Phosphorus	SM 4500-P-B, FMOD	0.005	0.010	mg/L
Total Nitrogen	SM 4500-N-C	0.050	0.100	mg/L
Total Suspended Solids	SM2540-D	0.5	1.0	mg/L
Chlorophyll *a*	EPA 446.0	0.5	1.0	mg/L
Pheophytin *a*	EPA 446.0	1.0	2.0	mg/L

7.1.2. Microbiology Analyses and Detection Limits

Microbiology analyses, methodologies, and associated detection limits are summarized in Table 4. The King County Environmental Laboratory will perform all microbiology analyses.

Table 4 Microbiology analyses.

Analysis	Method	MDL (cfu/100ml)	RDL (cfu/100ml)
Fecal coliform by Membrane Filtration	Std Method 19th ed., 9222D	1	N/A

7.1.3 Phytoplankton

Phytoplankton will be identified to the genus level and by species if possible. Taxa will be categorized by Dominance-Subdominace-Presence, based on a combination of relative frequency and cell size. All phytoplankton work will done in-house, looking at samples fixed with Lugol's solution and using a Nikon compound microscope (Eclipse E200).

7.2. QC Requirements

7.2.1. QC Practices for Conventional Analyses

Laboratory QC samples for conventionals analyses and associated control limits are summarized in tables 5 and 6 respectively. These QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples.

Table 5 Chemistry QC

Parameter	Blank	Replicate	Matrix Spike	LCS
Ammonia Nitrogen	1 Per Batch	1 Per Batch	1 Per Batch	1 Per Batch
Nitrate Nitrogen	1 Per Batch	1 Per Batch	1 Per Batch	1 Per Batch
Orthophosphate	1 Per Batch	1 Per Batch	1 Per Batch	1 Per Batch
Total Phosphorus	1 Per Batch	1 Per Batch	1 Per Batch	1 Per Batch
Total Nitrogen	1 Per Batch	1 Per Batch	1 Per Batch	1 Per Batch
Total Suspended Solids	1 Per Batch	1 Per Batch	n/a	1 Per Batch
Chlorophyll *a*	1 Per Batch	1 Per Batch	n/a	1 Per Batch
Pheophytin *a*	1 Per Batch	1 Per Batch	n/a	1 Per Batch

Table 6 Recommended Chemistry QC limits

Parameter	Blank	Replicate	Matrix Spike	LCS
Ammonia Nitrogen	< MDL	≤ 20%	75 – 125%	85 – 115%
Nitrate Nitrogen	< MDL	≤ 20%	75 – 125%	85 – 115%
Orthophosphate	< MDL	≤ 20%	75 – 125%	85 – 115%
Total Phosphorus	< MDL	≤ 20%	75 – 125%	85 – 115%
Total Nitrogen	< MDL	≤ 20%	75 – 125%	85 – 115%
Total Suspended Solids	< MDL	≤ 25%	n/a	80 – 120%
Chlorophyll *a*	< MDL	≤ 25%	n/a	90 – 110%
Pheophytin *a*	< MDL	≤ 50%	n/a	n/a

7.2.2. QC Practices for Microbiology Analyses

Routine QC analyses for Microbiology monitor method performance of each sample analysis batch for each method. A sample analysis batch should not exceed 20 samples of the same matrix which are all prepared together and analyzed using the same reagents, media, equipment and by the same analyst(s). The QC samples to be tested with this set of samples are described below:

7.2.2.1. Laboratory Duplicates

Laboratory duplicates are prepared for each matrix type at a frequency of 1 per batch or 5%, whichever is more frequent. The duplicate must be processed through all preparation and incubation steps used for the original sample. The acceptance limits are based on a 95% confidence limit as described in the appropriate reference methods.

7.2.2.2. Negative Controls

A negative control is prepared at a frequency of 1 per batch or 5%, whichever is more frequent. The negative control should show an appropriate qualitative response for the test organism and should not be identified as containing the target organism.

- For Fecal Coliform, the negative control organism is *Proteus sp*. or *Enterobacter sp*.

7.2.2.3. Positive Controls

A positive control is prepared at a frequency of 1 per batch or 5%, whichever is more frequent. The positive control should show an appropriate qualitative response for the test organism.

- For Fecal Coliform, the positive control organism is *E. coli*.

7.2.2.4. Sterility Controls

Pre-filtration and post-filtration blanks are prepared each working day to evaluate the sterility of the dilution water and filtration equipment. These sterility controls are considered acceptable if no growth is detected.

7.3. Documentation/ record keeping

The King County Environmental Laboratory will provide a 30-day turnaround time for all analytical data. All data received from subcontractor laboratories will be reported to the King County Environmental Laboratory in a format that will allow an appropriate level of QA/QC review.

8. LABORATORY AND FIELD DATA REVIEW AND REPORTING

8.1. Data review, verification and validation requirements

Chemistry and microbiology data will undergo standard QA review within each laboratory unit according to the Environmental Lab's QA Manual and method-specific SOPs. If needed, the data will be flagged accordingly. The LPM will review the lab unit QC results. If there are any anomalies or qualified data, the LPM will provide a narrative explaining the reason for such qualified data. This narrative will accompany the data report when it is transmitted to the project and program managers. If there are no QC issues associated with the data report, the project and program managers will receive only a copy of the lab unit QC documents accompanied by the data report. All reviews will be done on an event basis. This level of QA review is necessary to provide the project and program managers with the level of information needed to correctly interpret the data.

9. HEALTH AND SAFETY PLAN

Field crew will use a county vehicle outfitted with cellular phone and first aid equipment. A canoe will be used to collect the lake samples and will be outfitted with lifejackets and a safety bag with first aid equipment.

10. APPENDIX A: